Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Development of Applications Enabled by the Atmospheric Infrared Sounder (AIRS)

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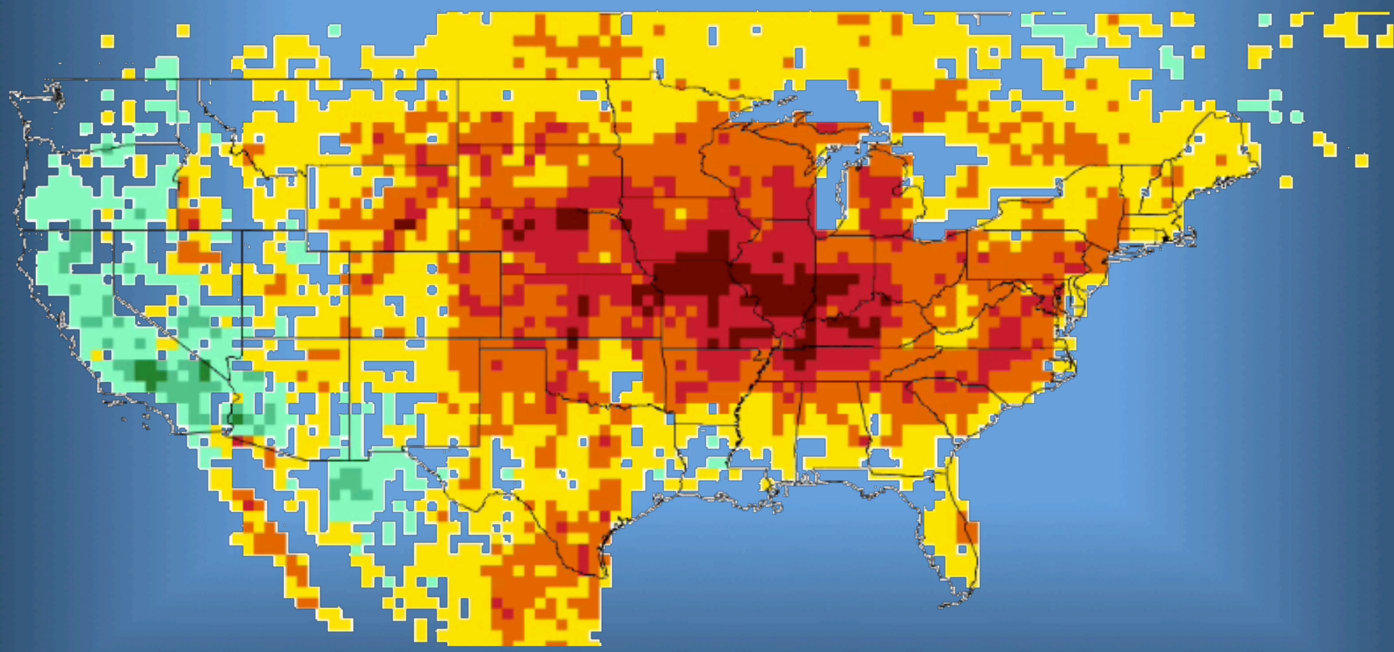


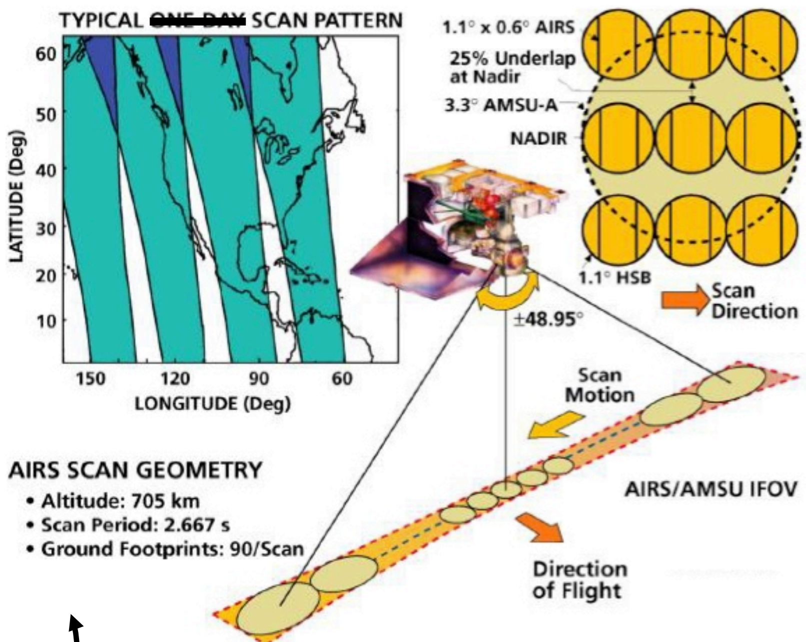
EUMETSAT Conference, Rome, October 2-6 2017

AIRS in brief

AIRS was launched in May 2002

Nearly 15 years of self-consistent data
Weather: Significant forecast impact
Climate: Can now study climate variability, can soon study trends
Research: Widely used in process studies

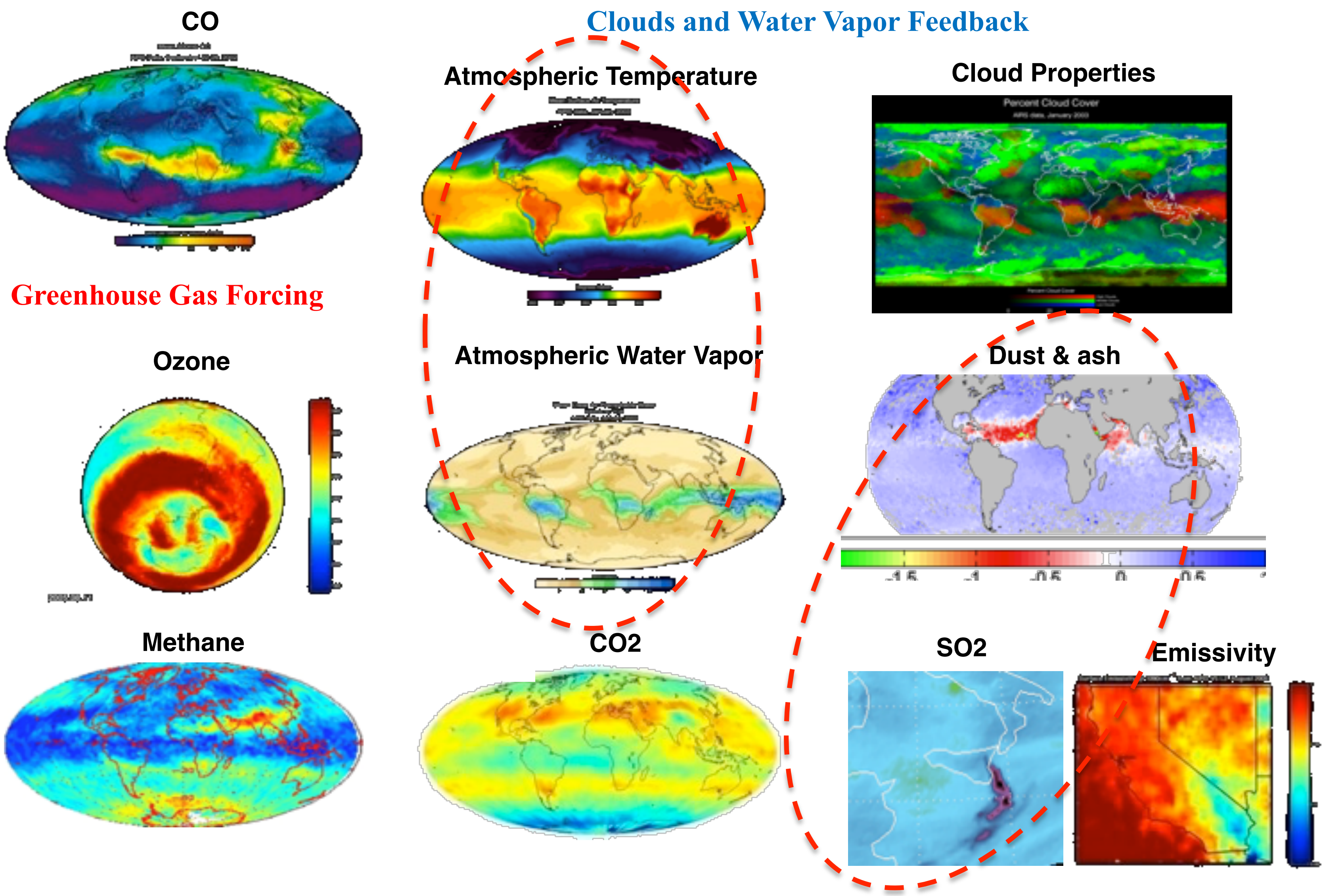
Geometry and sampling:



1. AMSU footprint, 45 km across at nadir, contains 9 AIRS spectra
   – THIS IS THE RETRIEVAL GRANULARITY.
2. Viewing swath 30 AMSU footprints or ~1650 km wide.
3. The result: 2,916,000 IR spectra and 324,000 retrievals per day

See http:airs.jpl.nasa.gov

Key geophysical products



APPLICATION: Volcanic eruptions

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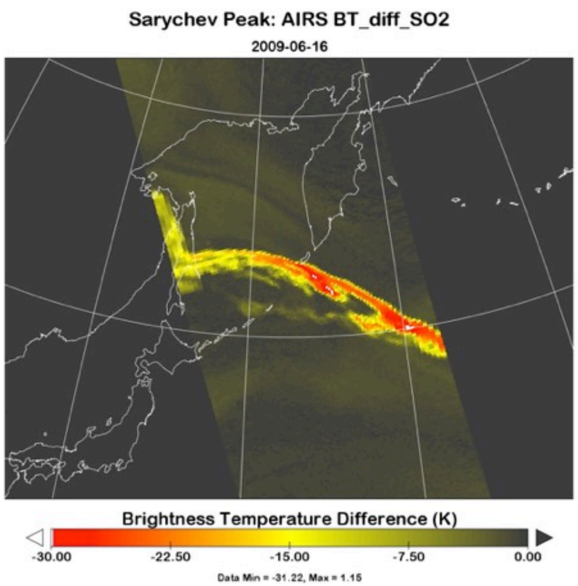
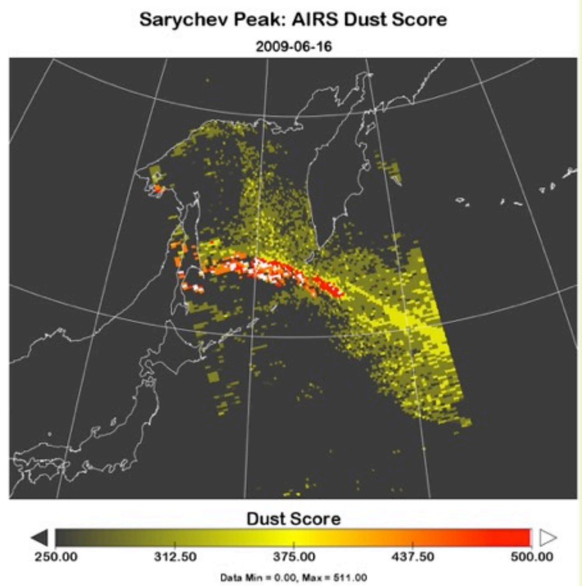
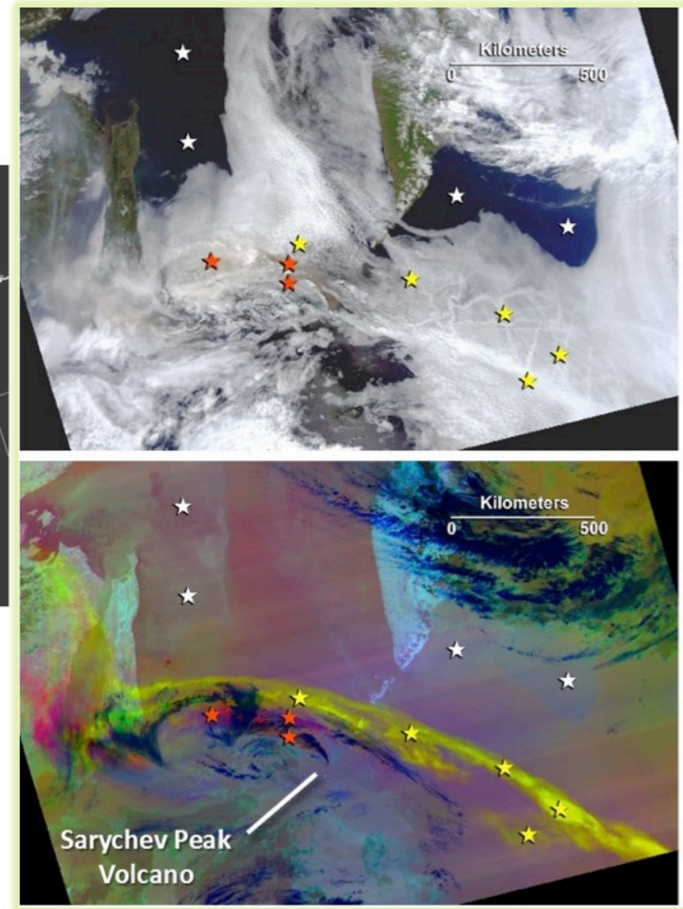
AIRS Standard Products Re-Purposed as Eruption Detection Tools







$\Delta T_b = T_b\,(1361.44\ cm^{-1}) - T_b\,(1433.06\ cm^{-1})$
AIRS SO_2 Flag, $\Delta T_b < -6$ K, Does Not Show Distribution of SO_2 Within Plume

Dust Score is Sensitive to Volcanic Ash
Scores > 380 Indicate High Probability of (Silicate) Dust

MODIS RGB (top)
AIRS-MODIS TIR (bottom)

☆ Clear Path
★ SO_2 Plume
★ Ash Plume

- Define Thresholds for Volcanic SO_2 and Ash Detection Based on AIRS Archive (2002 – Present)
- Thresholds will be used to Trigger Retrievals of SO_2 Column and Ash Mass Concentration

AIRS volcano “rapid response”

Near-realtime products

High Level Overview

- All processing done at JPL
- Short-term local 3-week rolling archive
- Long-term archive on GIBS
- AIRS volcano page to be established on NASA SO2 page at so2.gsfc.nasa.gov

JPL Alert System
Check each granule for SO2 AND dust threshold breach

ON TRIGGER

Capture granule lat/lon → Build Worldview URL → Make images → Post images on AIRS volcano page → Email notifications

Make images:
SO2 BT diff
Dust score
SO2 load, multi-height
Ash & dust load, multi-height
Cloud Fraction + SO2 overlay
(KML, GeoTIFF, PNG, JPG formats)

Email notifications:
1. JPG image(s), clickable to image on volcano page
2. link to AIRS volcano page
3. Worldview URL

Send to
- Curated list of recipients
- JPL Disaster reps

AIRS vs. MODIS

- AIRS lets us identify plume components uniquely
- The combined use of AIRS + MODIS data is stronger than the use of a single data set
- VIIRS + CrIS will extend this capability past the Aqua mission lifetime.

- Head to head comparison of MODIS and AIRS products shows that AIRS is competitive, given the large difference in spatial resolution
- AIRS products will suffer, in comparison with MODIS, for low-altitude, low-yield eruptions, (but such eruptions are rarely news-worthy!)

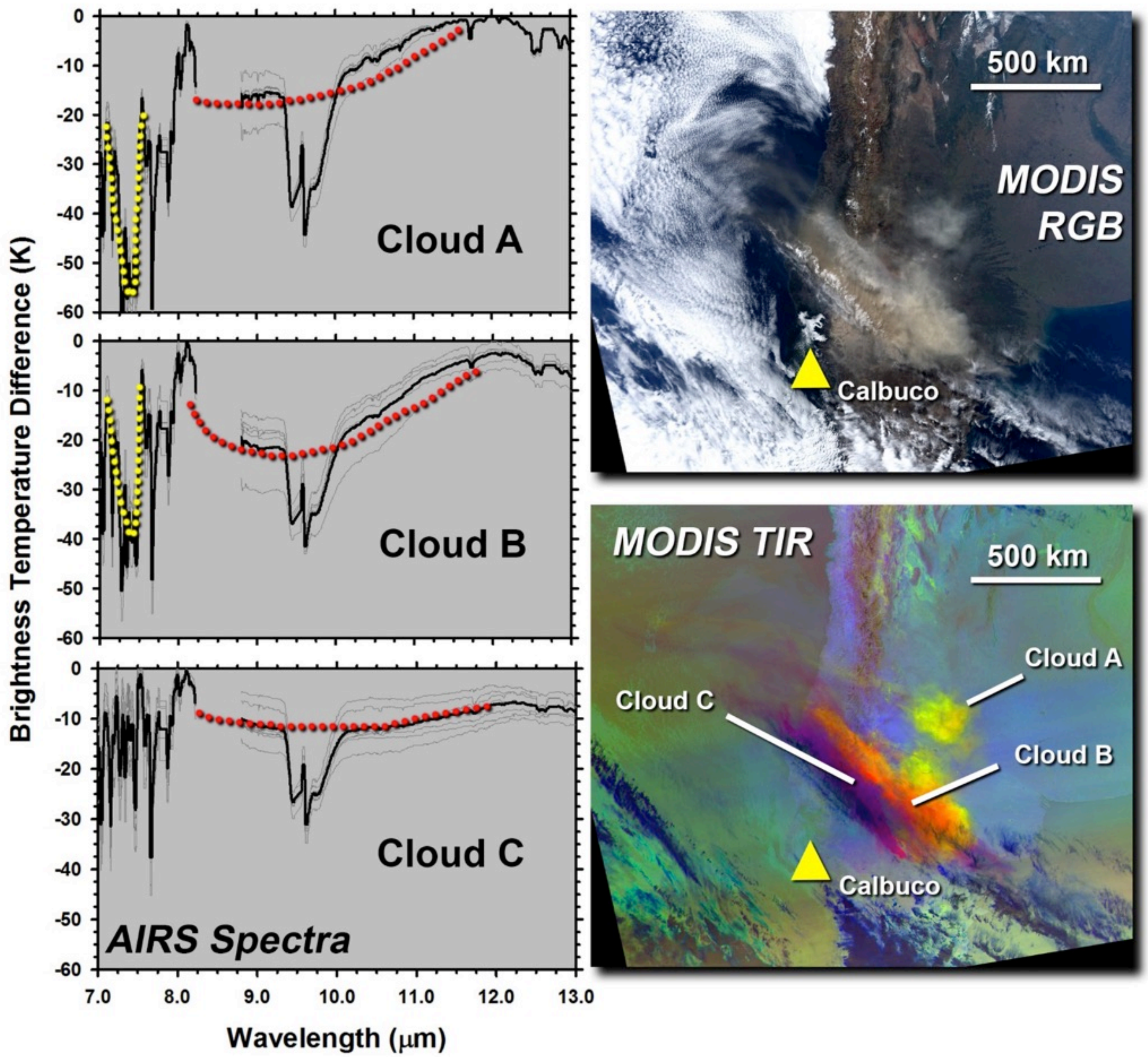
So why do we need AIRS?

- The MODIS AOT tells us that there are attenuating aerosols aloft, but gives us no unique information on the composition of the aerosols
    - In fact, the MODIS aerosol products give use a choice of 10 different aerosol composition/size models!
    - Ditto for MISR, or any aerosol product based on vis-swir scattering
- The AIRS "dust score" is used to trigger further analysis but does not give us composition, except that the score is sensitive to silicate minerals
- The AIRS spectra show the effect of ash

Volcanic eruptions: Calbuco, Chile (2015)

Calbuco Volcano, Chile
2015-04-23
18:35 UTC

- MODIS provides spatial context + coarse spectral information
- AIRS provides fine spectral information = unique identification of plume components
- CrIS + VIIRS will extend capability post- EOS



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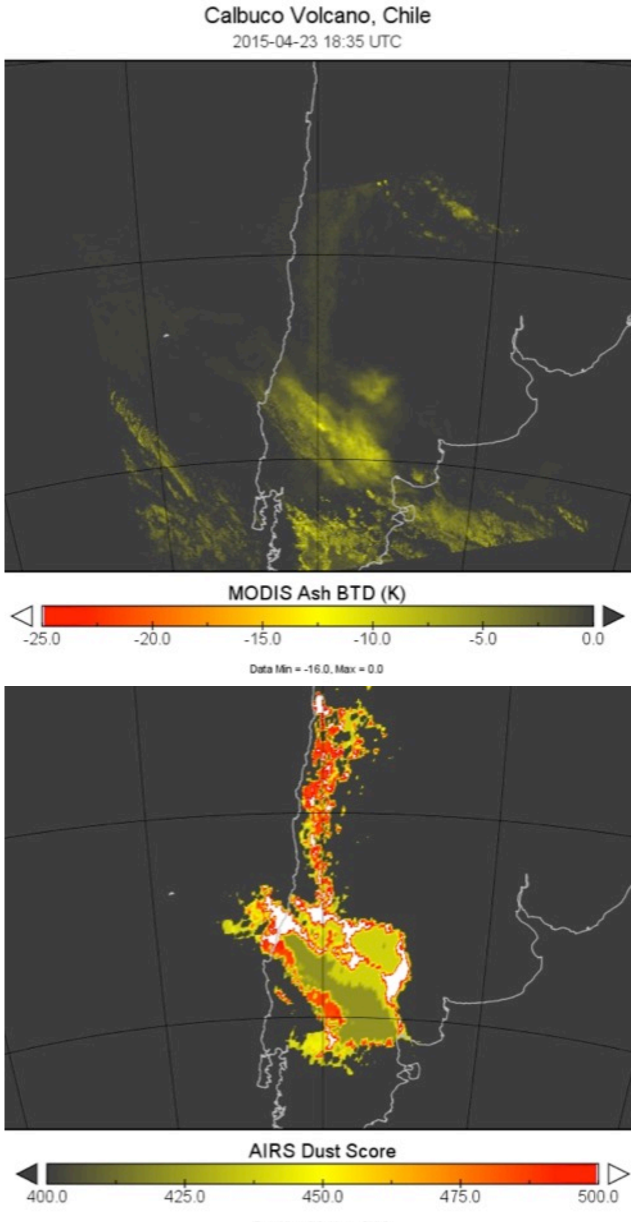
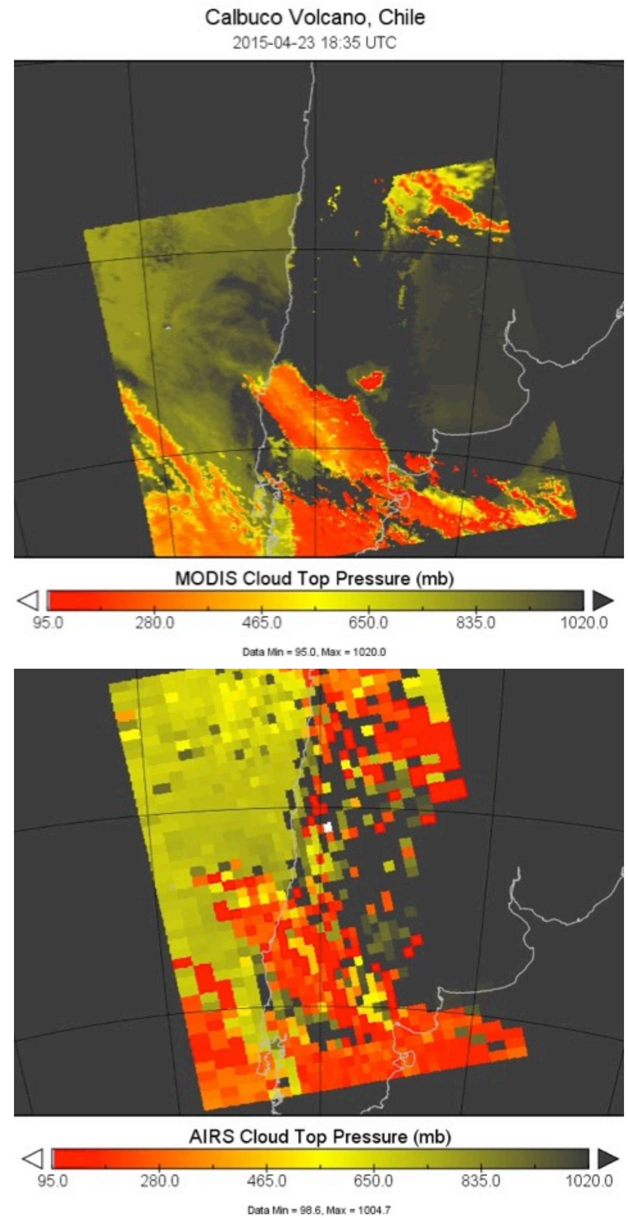
Calbuco: AIRS vs. MODIS (1)

MODIS ash ΔTb
vs.
AIRS dust score

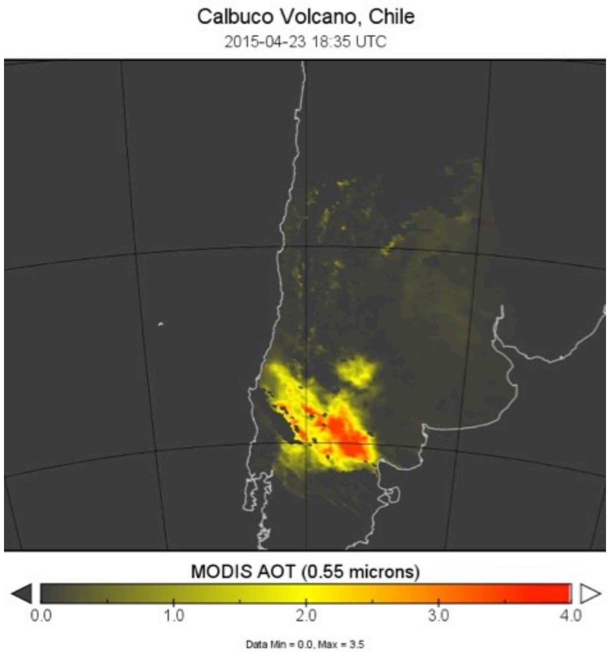


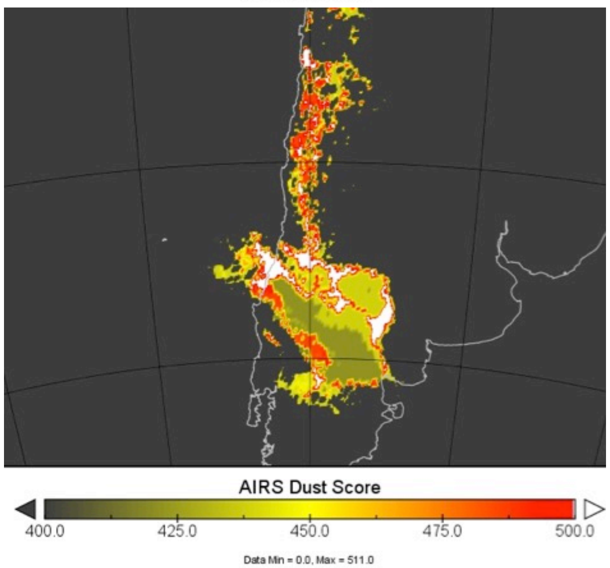
Cloud top pressure
MODIS vs. AIRS



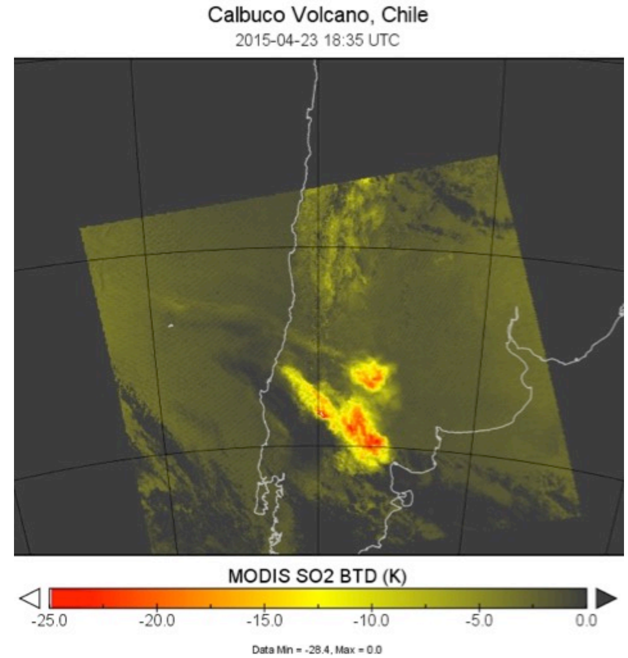
Calbuco: AIRS vs. MODIS (2)

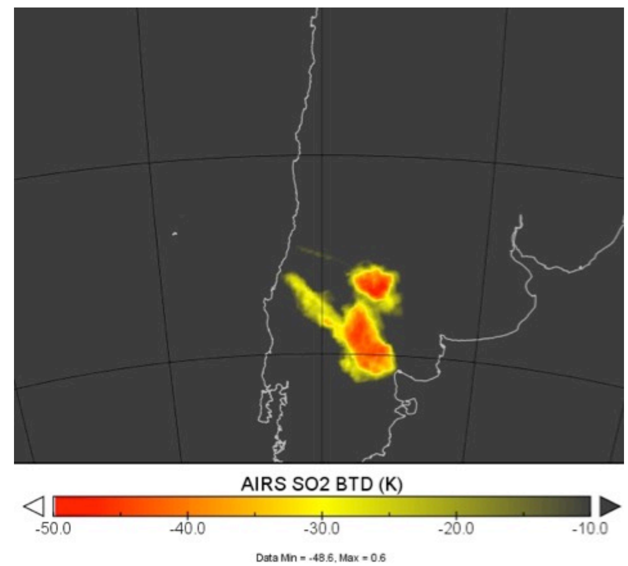
MODIS aerosol optical depth
vs.
AIRS dust score





SO_2 ΔTb
MODIS vs. AIRS





APPLICATION: Drought and wildfire

Key parameter: Vapor Pressure Deficit

Vapor Pressure Deficit is a key parameter for several AIRS applications
Derived from near-surface air-T and q (RH)

VPD = current vapor pressure – saturation vapor pressure:

$$VPD = c1\ \exp(c2xT_{mean}/c3+T_{mean}) - c1\ \exp(c2xTd_{mean}/c3+Td_{mean})$$

(Td: dew point temperature)

- **VPD has stronger correlation with some near-surface conditions than T or RH**
  - **Meteorological drought**
  - **Fire conditions**
  - **Vector borne disease**
  - **Surface evaporation**

Drought: Background

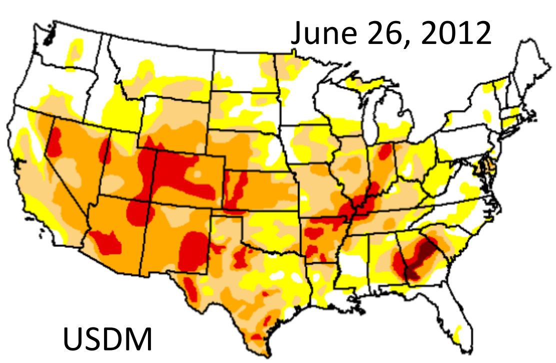
Can we detect signal of drought onset earlier than that suggested by precipitation deficit?

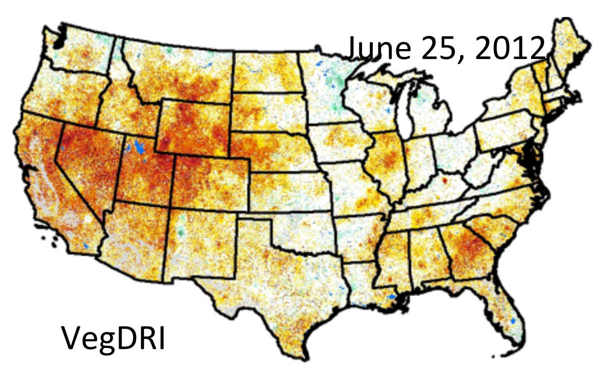
Three kinds of drought:

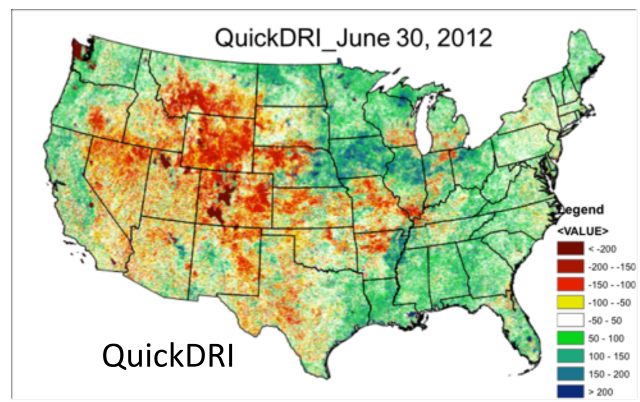
- Meteorological Drought: **SPI**-Standardized Precipitation Index (P only) ← AIRS
- Hydrological Drought: **SRI**-Standardized Runoff Index (Runoff or River Discharge)
- Hydrological Drought: **SRI**-Standardized Runoff Index (Runoff or River Discharge)

Widely-used composite drought products using precipitation :

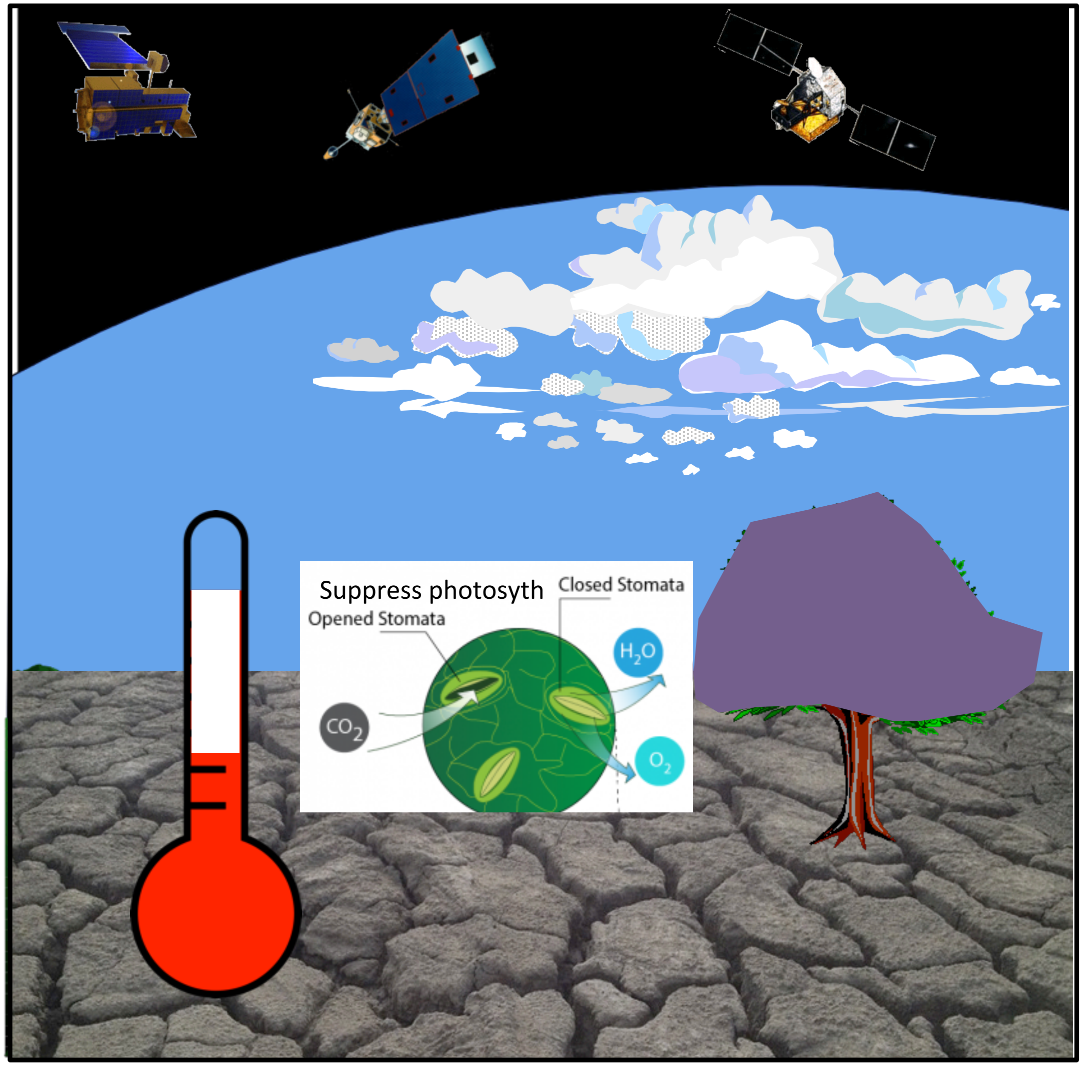
- U.S. Drought Monitor (USDM) map: Short term drought, 1-3 month precipitation; long-term, 6-60 months.
- Vegetation Drought Response Index (VegDRI): 36-week SPI;
- Quick Drought Response Index (QuickDRI): 1-month SPI;







The life of plants



Environment:

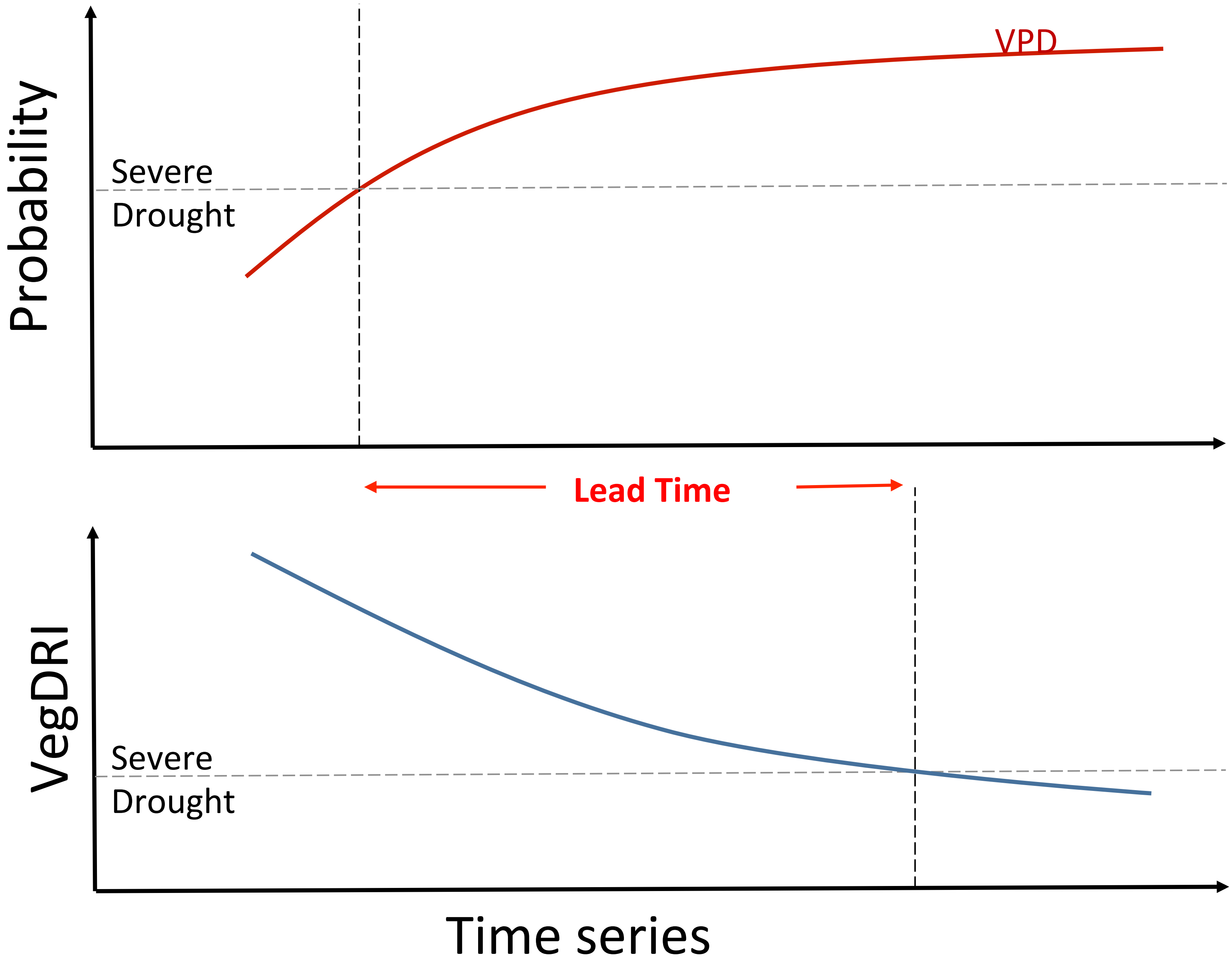
- T ↑ RH ↓ VPD ↑
- Precip ↓
- Soil Moisture ↓

Vegetation:

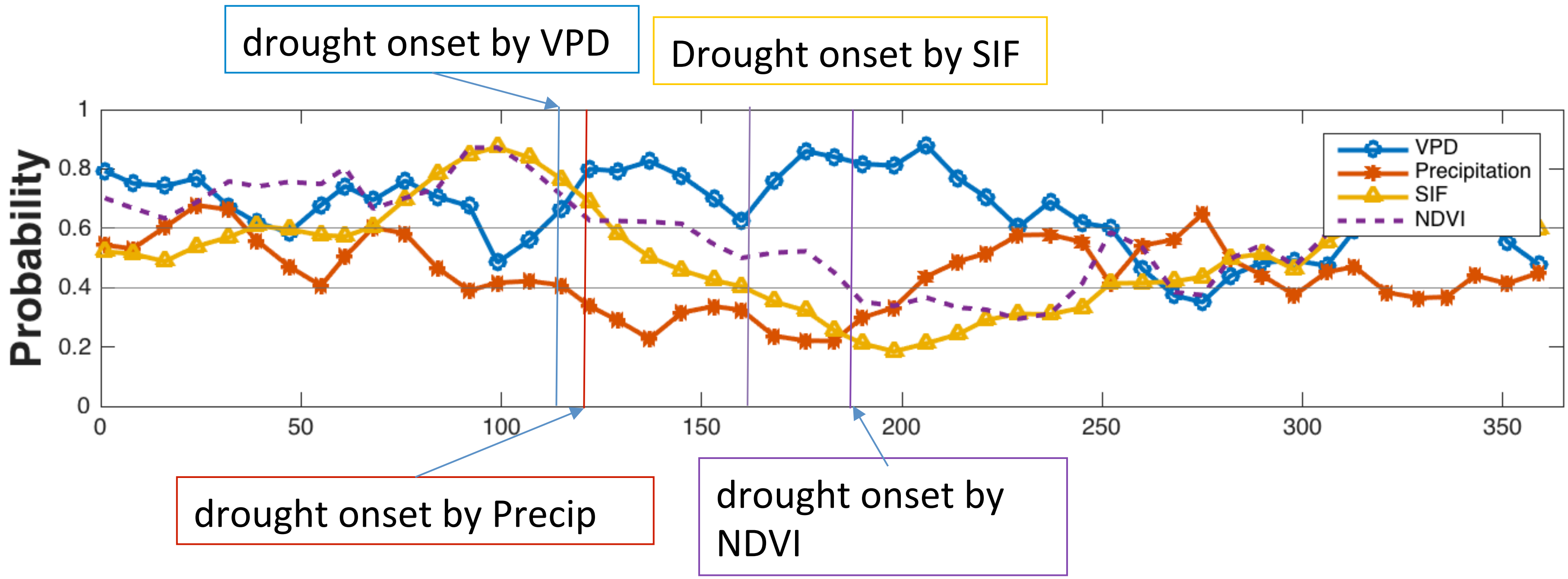
- SIF ↓ ↓
- NDVI ↓

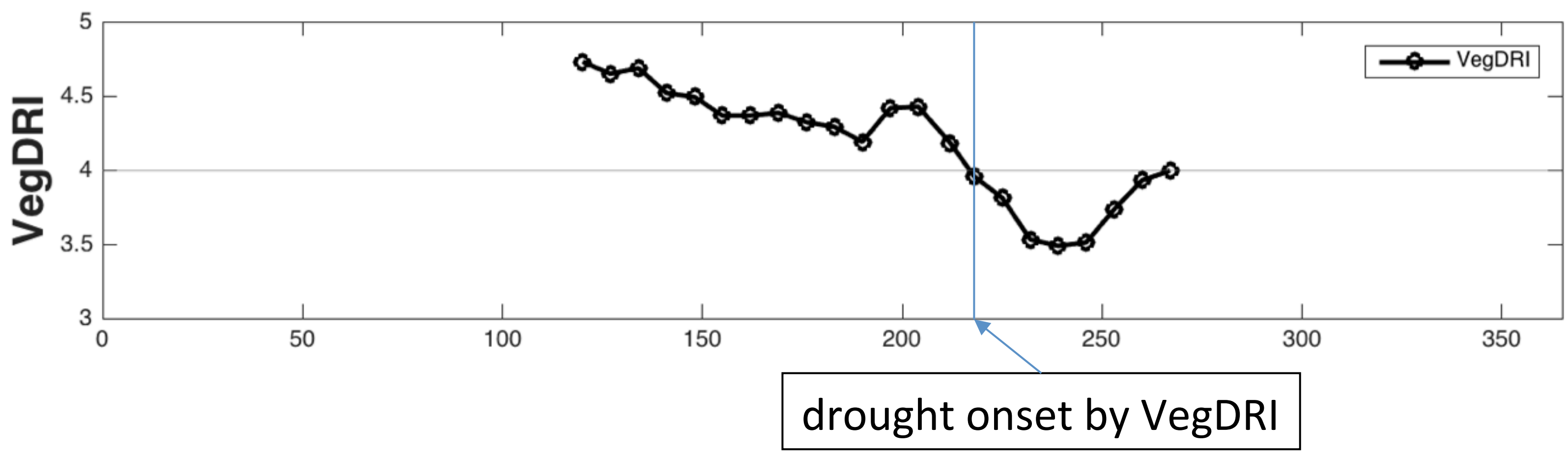
SIF = Solar-induced chlorophyll fluorescence
Low value ←→ plant are not growing
NDVI = Normalized difference vegetation index
Low value ←→ plants are losing leaves

VPD – A leading indicator



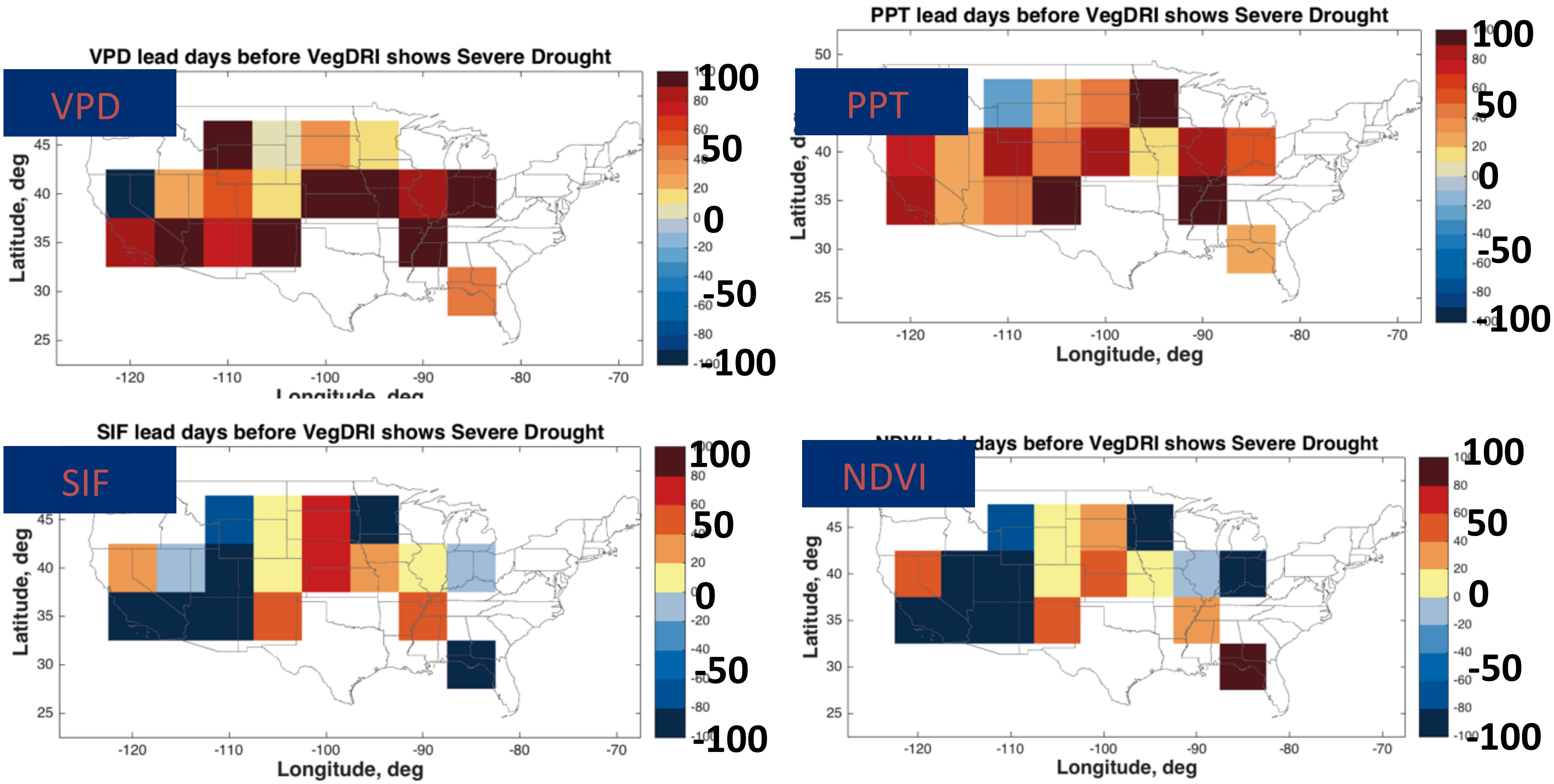
Drought: Detection lead time (1)





Drought: Detection lead time (2)

The lead/lag times relative to VegDRI drought onset detection

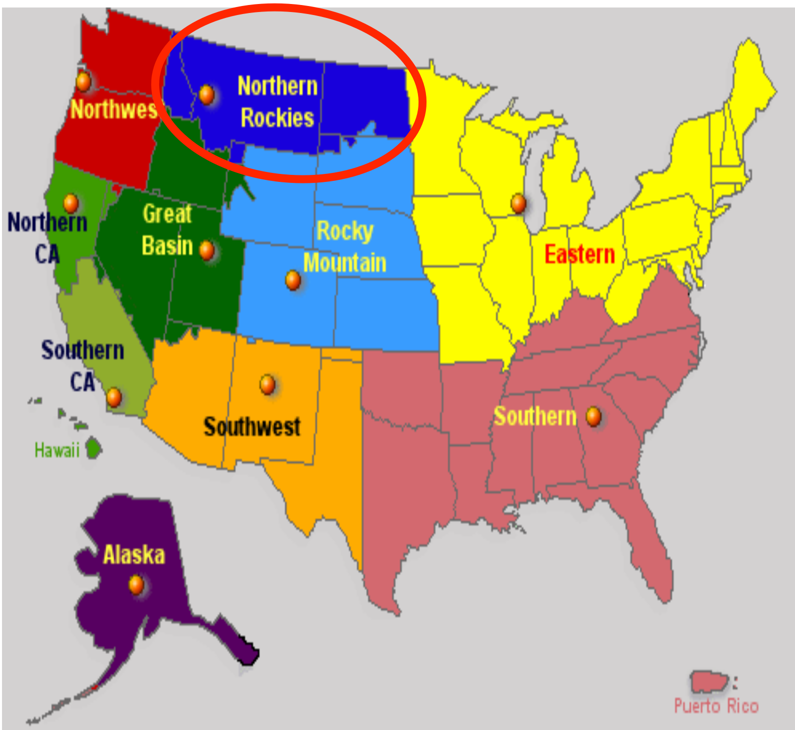


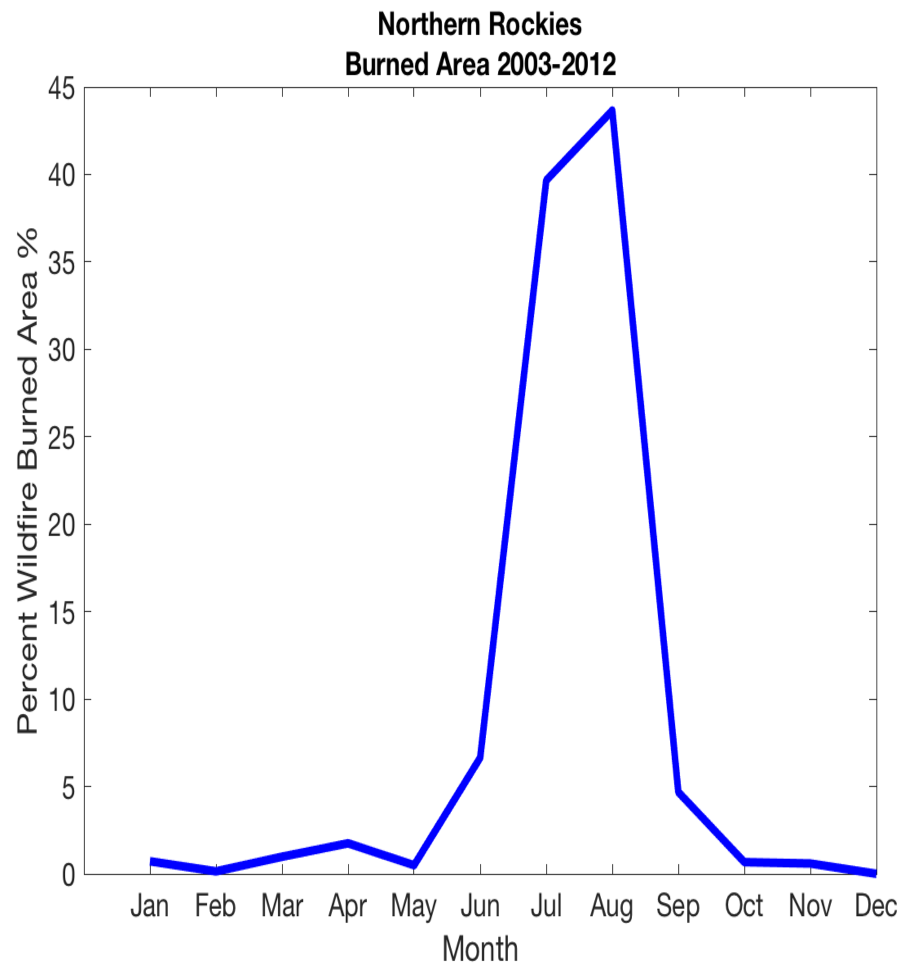
The lead time (days) based on (a) VPD, (b) Precipitation, (c) SIF, and (d) NDVI relative to VegDRI Severe Drought onset.

Note that, SIF and NDVI are related to vegetation health, which are different from environment variables, e.g. VPD, PPT.

APPLICATION: Wildfire conditions

Case study: Northern Rockies





Burned Area Source:
US Forest Service
Fire Program Analysis Fire-Occurrence Database (FPA-FOD)

Fire-condition detection: Methodology

Hydrologic Data Input

- Monthly NASA AIRS Vapor Pressure Deficit (VPD) 2003-2012
- Monthly NASA GRACE assimilated Soil Moisture (SM) 2003-2012

✓ Spatial Resolution: 0.25°

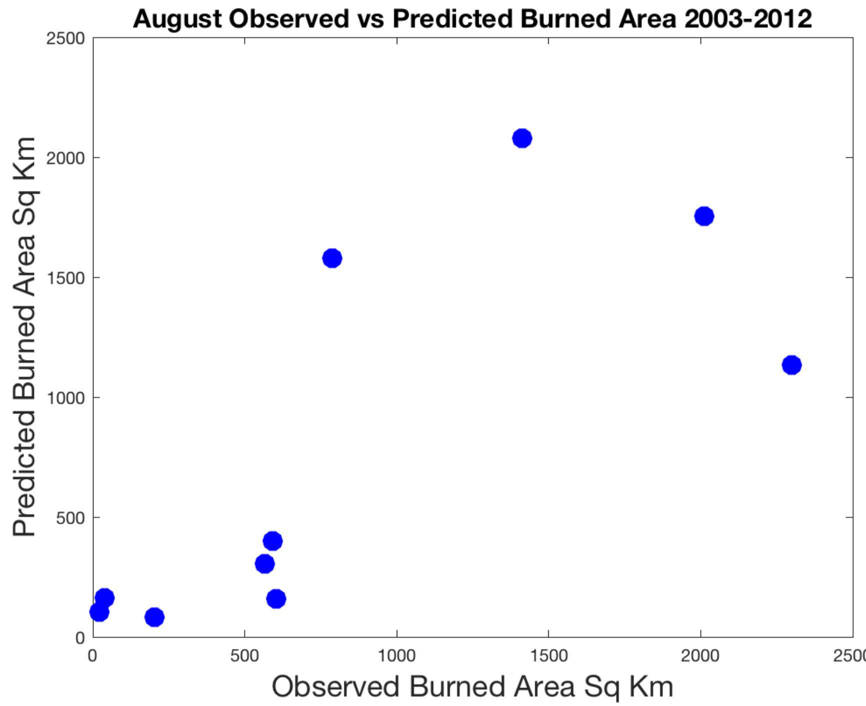
Methodology

Build a linear regression model based on different combinations on n-month lead Vapor Pressure Deficit (VPD) and n-month lead Soil Moisture (SM)

$$\textbf{\textit{Burned Area}} = \boldsymbol{a} + \boldsymbol{b} \times \textbf{\textit{VPD}} + \boldsymbol{c} \times \textbf{\textit{SM}}$$

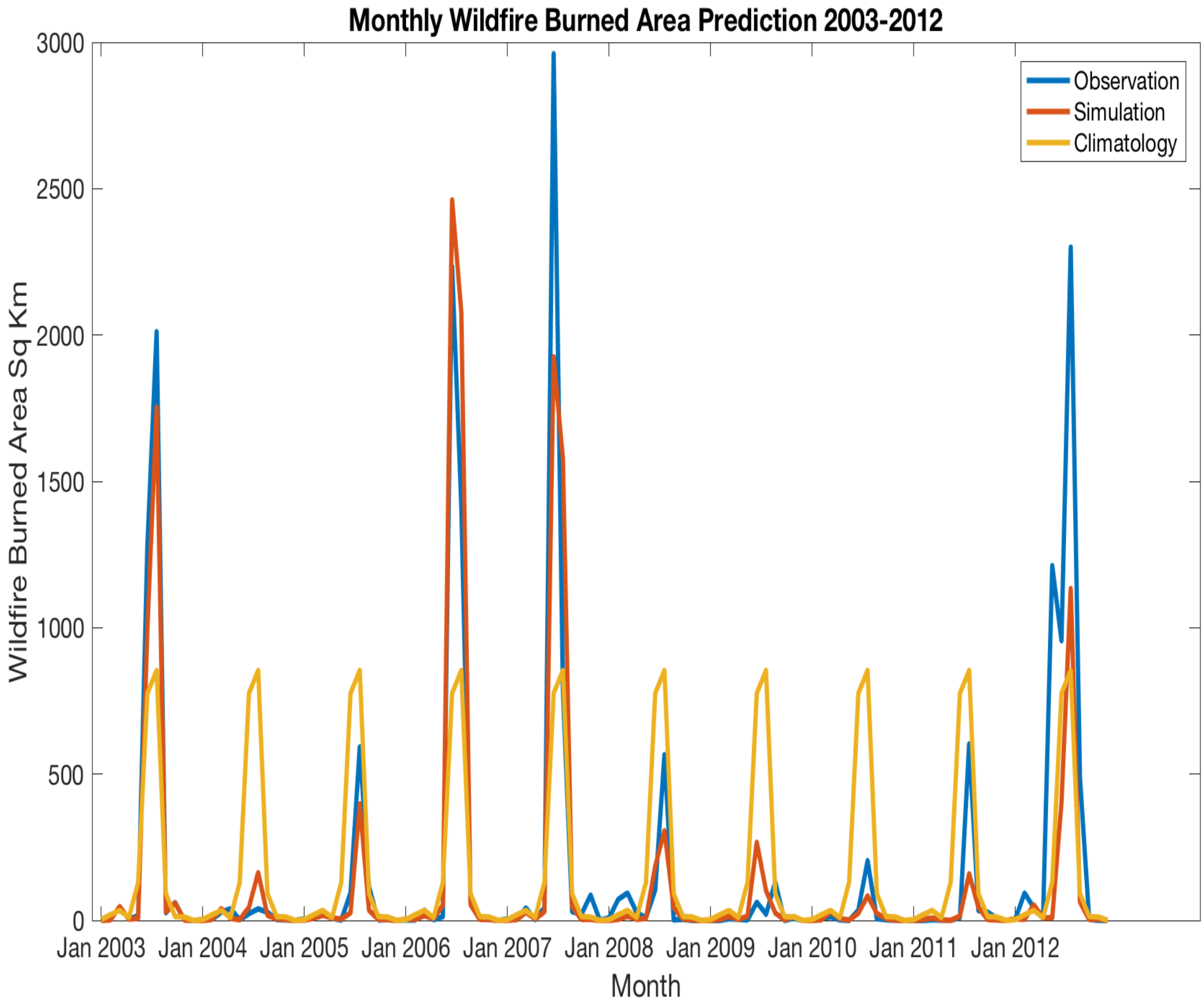
➢ Best Combination: 1-month lead VPD and 1-month lead SM

Results



Correlation: 0.75

Fire-condition detection: Performance



APPLICATION: Influenza outbreaks

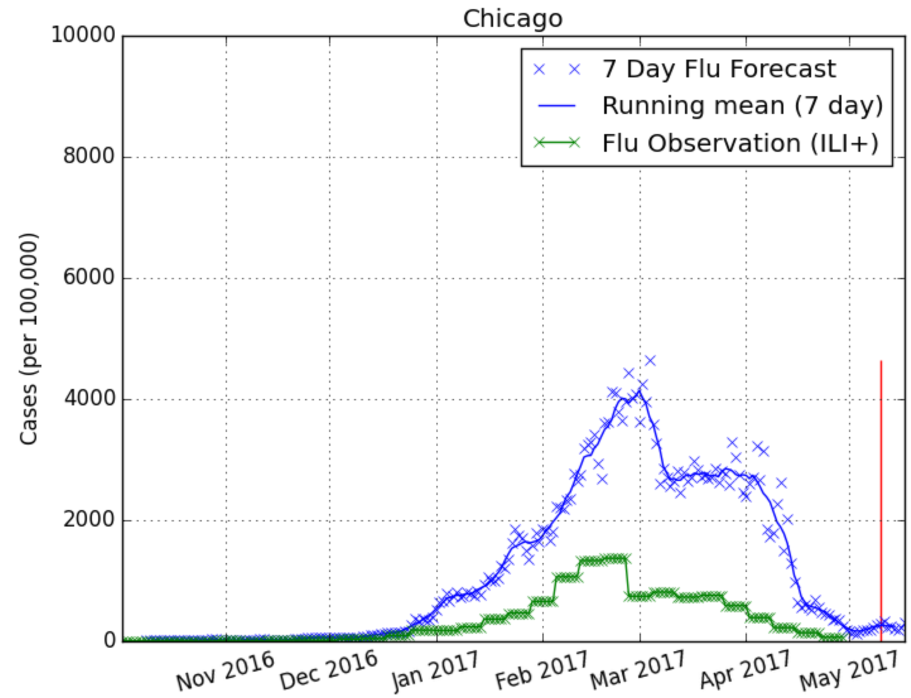
- Influenza incidence generally peaks in winter (temperate regions), but specific timing, magnitude and duration of individual local outbreaks in any given year is variable and not well explained.
- Studies point to absolute humidity as leading driver for seasonal flu outbreaks (e.g., Shaman et al., 2010)
- Potential mechanisms: Effect on carrier droplet sizes, human defense (mucous membranes) and virus survival times
- We have used AIRS data to explore this hypothesis (as well as the role of temperature), lending further support for it and informing our modeling/ prediction efforts
- The goal is to provide predictions of influenza outbreaks (timing and intensity) for a given city/region
- Great potential value for public health – guiding mitigation/response efforts, planning and stockpiling of vaccines and drugs, management of hospital resources

Influenza application: Preliminary results

- We have built a humidity-driven prediction system for influenza outbreaks
- Numerically solves ODEs for number of susceptible and infected people in a population
- Effective infection rate modulated by humidity
- Most recent values of AIRS near-surface specific humidity as well as NCEP humidity predictions regularly incorporated into the model
- 'Observational' data for influenza incidence from CDC/Google assimilated to make analysis and re-initialize model
- Ensembles of forecasts run with different model parameter values drawn from distributions reflecting limited constraints
- Retrospective simulations also performed using AIRS data for US cities/states/regions as well as South African provinces

- The system has been running quasi-operationally for several US cities

Example results for the 2016-2017 season



- Timing and relative behavior of influenza outbreaks generally captured fairly well, while getting absolute numbers of affected people is more challenging

APPLICATION: Vector borne disease

- **Dengue Fever** is the most common mosquito-borne virus in the world
- Carried by Aedes aegypti mosquitos (same as Zika, Chikungunya and Yellow Fever) – strongly affected by environmental conditions
- Temperature affects mosquito development and reproduction, frequency of feeding, virus incubation period and geographical range of the vector (tropics and sub-tropics)
- Precipitation provides breeding sites and stimulates egg hatching, but can also hurt habitats through flooding and humidity has also been identified as a substantial factor affecting favorable conditions for the vector
- Typically expect effects of temperature and humidity to take 6-8 weeks
- We are exploring the application of AIRS climate data to the prediction of dengue fever incidence.
- An ultimate goal is to create and implement an improved prediction model for Dengue.
- We have done a focused study on Dengue fever in Mexico, from 2003-2015
- Significant Dengue incidence in varied climate conditions, with weekly Google Dengue Trends data available at state level as an estimate of disease activity
- AIRS variables: surface air temperature, specific humidity, relative humidity
- Examined trends, patterns and time lags, regression models of varying complexity

Summary

AIRS applications show great promise

- Volcanic eruptions: Unique information about composition of volcanic clouds (ash, SO_2)
- Drought: VPD gives leading indicator of meteorological drought
  - Provisionally adopted by U.S. Drought Monitor
- Fires: VPD gives leading indicator of fire conditions
- Disease: VPD measures conditions conducive to influenza and mosquito-borne diseases

These area are under active development

- But we welcome collaborations!